Fire Management Notes

Fire Management Notes

An international quarterly periodical devoted to forest fire management

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Danger Zone: The Wildland/Urban Interface

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In October 1871, a fire in Peshtigo, WI, killed more than 1,500 people and burned 1.2 million acres. The Peshtigo Fire occurred in the same month as the infamous Chicago Fire. But while everyone has heard of Mrs. O'Leary's cow, few have heard of the Peshtigo fire in which four times as many people died.

Ancient history? Not so!

The 1985 wildland fire season was the most severe of this century. By the end of the fiscal year, over 83,000 wildfires had burned almost 3 million acres, destroyed or damaged in excess of 1,400 structures and dwellings, caused the deaths of 44 civilians and firefighters, and cost the Federal, State, and local fire agencies and private industry over 400 million dollars in firefighting costs. Damage estimates to natural resources and property are not available, but probably run into the hundreds of millions of dollars.

The Southern States east of the Appalachian Mountains from Florida to Virginia, parts of New England, Idaho, Nevada, and central California were especially hard hit by wildfires. National mobilization was needed in the Western States and in the South to cope with wildfires. During the first week of July, a total fire mobilization of over 20,000 Federal and State firefighters was committed to fires in 13 Western States, including massive fires in California, Idaho, Oregon, and Nevada.

The loss of property was the worst since 1871 when the Peshtigo Fire destroyed entire communities. Major losses of buildings occurred in Florida, North Carolina, and California, but reports of structure losses have also come from Washington, South Carolina, Oregon, and New England. The number of structures saved by wildland firefighters is not known, but wildfire reports routinely listed "structures threatened" in daily status reports. Because protection of property and lives took priority, natural resource losses increased when fire forces were diverted to protect structures.

Last year's loss in lives and property is part of a developing trend. A major population shift from urban to suburban living in the years since World War II has greatly expanded what is now called the urban/wildland or woodland home environment—the zone where people are in contact with the wildlands for reasons not related to timber or other traditional forest uses. Although this trend has increased the general population's appreciation for the amenity values of forests, it has also greatly increased the number of primary residences, second homes, and retirement homes located in forests and brushlands. Vast areas of the United States contain high-value properties intermingled with flammable native vegetation.

Structural fire losses are increasing dramatically as more people build and live in proximity to flammable plant communities. Major loss of life is possible—in fact, inevitable. The problem is not, as is often believed, one unique to southern California. The extension of residential and commercial development into areas with high fire risk has been noted throughout the Nation—from the Georgia Piedmont and the sand plains of central Michigan to the Rocky Mountain foothills near Denver to northern New England.

Although current fire management practices make it unlikely that fires will ever again reach the huge proportions of those in 19th-century America, the risks to life, property, natural resources, and economic welfare are much higher today then ever before. Huge fires are not required for catastrophic losses in the modern wildland/urban interface. Even small fires can be killers— three homeowners died when an 8-acre fire swept their Baldwin Hills, CA. subdivision. Fire management must change in order to better prevent and suppress smaller, fast-moving single and multiple fires as a wildland/urban interface continues to expand. This change must occur nationally.

The task of protecting lives and property from wildfires in the wildland/urban interface poses one of the most critical and elusive prob-

Most forest fire suppression personnel are inadequately prepared for fighting structural fires....

Losses of property and life as a result of fires in the wildland/urban interface have been increasing dramatically in recent years.

lems faced by wildfire protection agencies. Wildfire protection agencies have broken the problem down into several parts:

• Fire managers are unable to reliably predict erratic fire behavior in mixture of structures, ornamental vegetation, and wildland fuels characterizing the interface. Physical fuel properties and moisture relations in these areas are not well understood, as they are governed by both natural and human-caused phenomena. Possible relationships among building and landscaping location, design, and construction, with respect to terrain and other structures, add to the complexity of fire behavior. For example, spotting (fires starting from flying em-

bers) is especially difficult to forecast due to the diversity of firebrand materials and unusually complex windflow patterns. Yet, spotting is the chief cause of structural fire ignitions in wildland/urban areas.

• Use of prescribed fire for hazard reduction (fires purposely set to remove undesirable vegetation) is made difficult by legal, political, and environmental concerns. Liability for damages to intermingled private holdings is a significant deterrent. In many cases, the very reason for living in the interface precludes the use of fire. Nonetheless, means must be found to manage fire hazards in the interface, while maintaining or enhancing desired environmental and economic

values.

• Many property owners are unaware of the wildfire threat, and fire safety ordinances and building codes are frequently inadequate, unenforced, or disregarded. A quintessential example is the insistence on flammable roof materials in the chaparral area of southern California, but similar attitudes are exhibited throughout the world. The design of subdivisions, also, continues to defy principles of fire safety. Many areas include narrow, winding, or dead-end roads with inadequate water systems. Lots are frequently too narrow to permit effective vegetation removal. Without strong motivation to change, homeowners and developers will continue to produce and maintain these dangerous communities.

• Most forest fire suppression personnel are inadequately prepared for fighting structural fires, whereas municipal fire departments are not always fully trained or equipped for wildland fire suppression. Although relatively new organizational systems for integrating a variety of fire protection resources and personnel have proven effective, the special demands of fires in the wildland/urban interface often force firefighting personnel to perform unfa miliar tasks. The need to meld structural and vegetation fire expertise on interface fires remains a formidable challenge.

The following actions and improvements are needed:

• Effective techniques and strategies to assess and manage fire hazards in the wildland/urban interface.

• Aids for planning, budgeting, and training for increased involvement in the residential/wildland interface to ensure a balanced capability in conducting structural and wildland fire suppression activities.

• Effective ways to educate property owners, land developers, insurance carriers, and local planners about vegetation fire problems and solutions.

• Fundamental knowledge about the physics of fire spotting and crowning in the wildland/urban interface.

• Knowledge about relationships of building design, materials, and landscaping with fire hazard and behavior.

• Improved understanding of why people build fire-prone homes in highly some flammable areas and how they respond to various motivational tactics to reduce vulnerability.

Who is responsible for the solution, the fire protection agency, the homeowner, the county planner? The responsibility for fire protection cannot be relegated to a single element of society. It calls for a combined effort. Just a few of the groups that share in the responsibility include:

• Homeowners
• Fire protection agencies
• Local and regional planners
• Media and communication experts
• Insurance carriers
• Builders, contractors, and architects
• Training and motivational experts

A truly integrated approach to the problem would greatly reduce its impact. We all must take a hand in solving the problem. We must strive to avoid a 20th-century Peshtigo fire. There is no justification for continuation of such a serious hazard to life and property. ■

Chilean Fire Course

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For the third time in as many years, firefighters from Central and South America, Spain, and Portugal gathered for training in various aspects of fire suppression. The most recent session, in late November and early December, 1985, was held near Santiago, Chile, rather than at the National Advanced Resource Technology Center (NARTC), Marana, AZ, where the two previous courses had been held. Through the combined efforts of 17 fire experts from Spain, Argentina, Chile, and the United States, 56 firemen representing 15 countries were trained in the latest techniques and philosophies of fire suppression. It is hoped that these individuals will be able to train others upon returning home.

During the 2 weeks of classroom training, the students were given courses in effective training techniques, fire behavior, prevention and detection, fuels management, organization for suppression, line construction, and air operations. A week of field exercises in early December, the start of the fire season south of the equator, afforded the students an opportunity to apply what had been presented in the classroom and to participate in a

Smokey Bear and his Chilean counterpart, Forestin the beaver, share the fire prevention message with Chilean schoolchildren.

prescribed burn. Field trips to national and private fire facilities and forest operations exposed the trainees to a fine example of organization and cooperation in an environment similar to what they are accustomed to at home.

Funding for Tercer Curso Internacional Avanzado, El Combate de Incendios Forestales was made available through the Agency for International Development (AID); Coropracion Nacional Forestales (CONAF), the national land managing agency of Chile; and the U.S.

Department of Agriculture Forest Service.

Smokey Bear made his first trip outside the United States, joining his Chilean counterpart, Forestin, a beaver, in promoting fire prevention. Smokey and Forestin visited several schools to pass out fire prevention material and appeared on national television.

As part of the continuing effort to attempt to share experience and technology among countries, Mexico plans to host a similar course in 1987. ■

Florida NIIMS Resource Inventory Program

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When the Florida National Interagency Incident Management System (NIIMS) Task Force was formed in 1982, one of its first actions was to form a logistics working team with the mission of developing a workable wildland fire suppression and support resources inventory for the State.

In order to inventory resources, it is first necessary to define the resources in such a manner as to ensure that the inventory is uniform and accurate. When considering fire suppression resources, however, enough flexibility must be built into the system to allow for variations in equipment while ensuring that the resource will do the job desired. Using the southern California definitions as a model, the team generated a list of resources adapted to the Southeast in general and Florida in particular. As outlined in national doctrine, resources are typed by capability, with lower numbers having generally greater capabilities.

After adoption of the resource definitions, an inventory method was devised. An inventory form was developed and distributed to the 17 Florida Division of Forestry districts for completion. Fire departments, forest industry cooperators, and Federal, State, and local agencies were surveyed by county unit. The resulting individual forms were then entered into a computer program.

The NIIMS resource computer program requires an IBM PC or compatible unit with 256 K memory. The software used is RBASE 4000 or 5000, published by Microrim, Inc., and the NIIMS program developed by the Florida Division of Forestry. The data-base size is limited only by the number of bytes per disk. The Florida data is currently stored on two double-density, two-sided floppy disks with approximately 364 K on each.

The two disks contain 1,268 address records, 1,813 radio records and 3,197 equipment records. This does not mean that there are 3,197 pieces of equipment recorded on those two disks; rather, it means that there are 3,197 lines or records available. The actual numbers of equipment recorded are 3,055 of type 1, 2,529 of type 2, 1,620 of type 3, and 1,099 of type 4, for a grand total of 8,303 pieces of equipment on record.

The data-base is divided into three relations—addresses and related data, radios and related data, and equipment types and amounts. For those using RBASE 5000, it may be desirable to rewrite the reports so that all three relations can be accessed at the same time.

To use the data, RBASE is loaded into the PC, the appropriate data disk is selected for the area involved, the data base is called up, and the program is run following the menu and instructions presented on the computer monitor. Editing of the data follows much the same process.

Through the menu, the program will:

1. Display contact data (address, telephone number, etc.) for agencies by cooperator, county, district, or statewide.

2. Display equipment data.

3. Display radio equipment.

4. Display all equipment and radio data for a selected cooperator, county, or district.

5. Search for specific kinds of equipment by county, district, or statewide.

6. Search for specific radio frequencies by county, district, or statewide.

Through the use of RBASE Extended Report Writer software, the data may be manipulated in various ways to produce mailing lists and other products.

For further information on the Florida NIIMS resource inventory, contact J.P. Greene or Jim Brenner at:

Florida Division of Forestry
Fire Control Bureau
3125 Conner Blvd.
Tallahassee, FL 32301

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The Plastic Sphere Dispenser Aerial Ignition System

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During the early 1960's, Australian foresters developed an aerial ignition system to ignite spot fires in large blocks of eucalyptus to consume litter and reduce a fire hazard (*1*). The system has been used in the United States since the early 1970's by private industry and some State divisions of forestry but was not approved for use by the Forest Service until 1986.

After safety testing by the Missoula Equipment Development Center (ED&T 4E42 P14, May 1985), the Southern Region (R-8) was asked to develop a user's guide on operating procedures prior to approval of the system by the Forest Service.

The operating guide was completed in February 1986, following a workshop held in Tallahassee, FL, and attended by representatives from each Forest Service Region and the Washington Office. Forest Service regulations require each operator to attend an 8-hour workshop to obtain certification to operate the dispenser.

How the Dispenser Works

The dispenser is portable (about 100 pounds) and can be mounted in a helicopter or fixed-wing-aircraft. The dispenser performs the function of systematically injecting the spheres with ethylene glycol (common antifreeze) and dispensing them from an aircraft at a rate of one each 2.6 seconds to three per second. At aircraft speed of 50 miles per hour, ignitions can be placed from 25 to 200 feet apart, as desired. Spacing can be varied by changing dispenser speed and/or aircraft speed.

The machine, a Premo-Mark III dispenser, is manufactured by Premo Plastics Engineering, Ltd., of Victoria, BC, Canada, and has proven to be a very effective aerial ignition system for both prescribed fire and burnout/backfire operations on wildfires.

About the size of Ping-Pong balls (33 mm), the plastic spheres contain 3 grams of potassium permanganate (KM_nO_4). When the spheres are injected with 1 milliliter of ethylene glycol, an exothermic reaction occurs in about 20 seconds, causing a flame sufficient to ignite fine fuels such as grass and pine needles. The system has also been used to ignite logging slash in clearcut areas and windrows of logging slash.

Use of Dispenser

Successful operations were conducted in February 1986 on the Appalachicola National Forest in Florida and the Kisatchie National Forest in Louisiana for fuels reduction burning. The England Air Force Base uses a portion of the Kisatchie National Forest as a firing range for A-10 aircraft. The Forest maintains the fuels on the area to

Figure 1—*The plastic sphere dispenser, mounted in a helicopter, is an effective ignition source for prescribed burns.*

Figure 2—*Plastic spheres containing potassium permanganate are injected with ethylene glycol, causing a flame sufficient to ignite fine fuels.*

prevent escaped wildfire ignited by Air Force use. This year, the Forest Service was assigned a 2-hour period to conduct a prescribed fire between strafing runs. The 3,500 acres were burned in 1 hour using the plastic sphere dispenser and a Bell 206-B helicopter. As the smoke cleared, the A-10's were flying again. Under these conditions,

it is imperative to complete the burning operation on time (the Air Force does use real bullets!). In another operation, 11,285 acres were burned in 9.4 hours of flight time over a 3-day period.

Cost of ignition is about $1 per acre. Plastic spheres are about 13 cents each, and antifreeze is inexpensive. One ignition spot per acre gives satisfactory results in the

piney woods of the South. The dispenser holds 1 gallon of antifreeze, which will inject 7,000 spheres. Thus, the dispenser has the capability of burning 7,000 acres without the helicopter returning to the helibase. If the burn boss is on board the helicopter, several areas can be burned during a single flight.

Linear spacing of ignition with the wind causes excessive heat as flank fires merge. A grid pattern with shorter flanks seems to produce less intensity (2).

Holding crews are needed on each burn unit but may progress to another unit because of short burn out time.

Efficiency and simplicity of the plastic sphere dispenser make it a desirable alternative ignition source for prescribed fire and wildfire burnout.

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2. Johansen, R.W. Prescribed burning with spot fires. Georgia For. Res. Pap. 49. Macon, GA: Georgia Forestry Commission; 1984. 7 p.

Fine Tuning the Incident Command System

James R. Abbott

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The Incident Command System (ICS) received an effective test on an interagency basis during the 1985 fire season. Although some units had little time to train and prepare, their first use of the system on actual fires went quite smoothly. This learning experience provided a practical means of bridging gaps between fire management systems and promoting an understanding of the differences in terminology and organization. It also provided an opportunity for experienced and knowledgeable people to critique the system and begin to suggest improvements that should be made. In addition, adaptations to local needs were considered.

As all agencies gain experience in using ICS there will be a natural tendency to propose modifications to meet specific local concerns. ICS is intended to be flexible enough to meet local needs; however, uncoordinated, independent changes could affect the system's utility as an interagency tool. It is also probably true that some changes are suggested only because new users do not fully understand how a particular problem is meant to be handled.

Other organizations such as law enforcement agencies and various emergency services are also adopting the system for their use. Although this expansion has many positive aspects it could produce more variations in application that may or may not be applicable to wildland fire. Thus, wildland fire agencies must carefully manage system changes if the intended interagency management benefits are to be realized.

The National Wildfire Coordinating Group (NWCG), through the ICS working team, provides the mechanism to coordinate the maintenance and revision of ICS with appropriate input and assistance from involved and interested agencies. Proposals suggested through team members, if accepted by the NWCG, will be incorporated into the system on a periodic scheduled basis. Without this cooperation, different agency approaches could soon create problems in applying the system in interagency situations.

Controlling system change through the NWCG has a high payoff for the agencies and States involved. Each idea and need can be examined by users in a way that features which enhance the system can in turn be adopted. Fine tuning in this way may require more time but the alternative of each agency modifying the system on a continual basis would seriously detract from the usefulness of the system.

The ICS working team has a set process for considering all suggestions. The process used for considering all suggestions is shown in figure 1.

What can you do if you have a suggestion for improving the Incident Command System?

- Analyze and document the benefits, costs, and consequences of the proposal.
- Review the proposal with agencies that you work with locally to obtain their ideas.
- Submit the proposal through agency channels or to the author or an ICS working team member. ∎

No further action 16

NWCG submits to appropriate entity for implementation 14

NWCG returns to ICSWT with instructions 17

Yes

No

NWCG disapproves 15

No

No

NWCG approves proposal 13

Yes

Submit proposal to NWCG with recommended action 12

No

Proposal or suggestion (Input) submitted to ICSWT 1

ICSWT evaluates input 2

Input must be returned to sender for more data 3

No

Input requires study or development 7

No

ICSWT prepares proposal in final form 9

Outside review needed 10

Yes

Yes

Yes

Return to sender with explanation or request 4

ICSWT makes assignment for further study 8

Submit to review 11

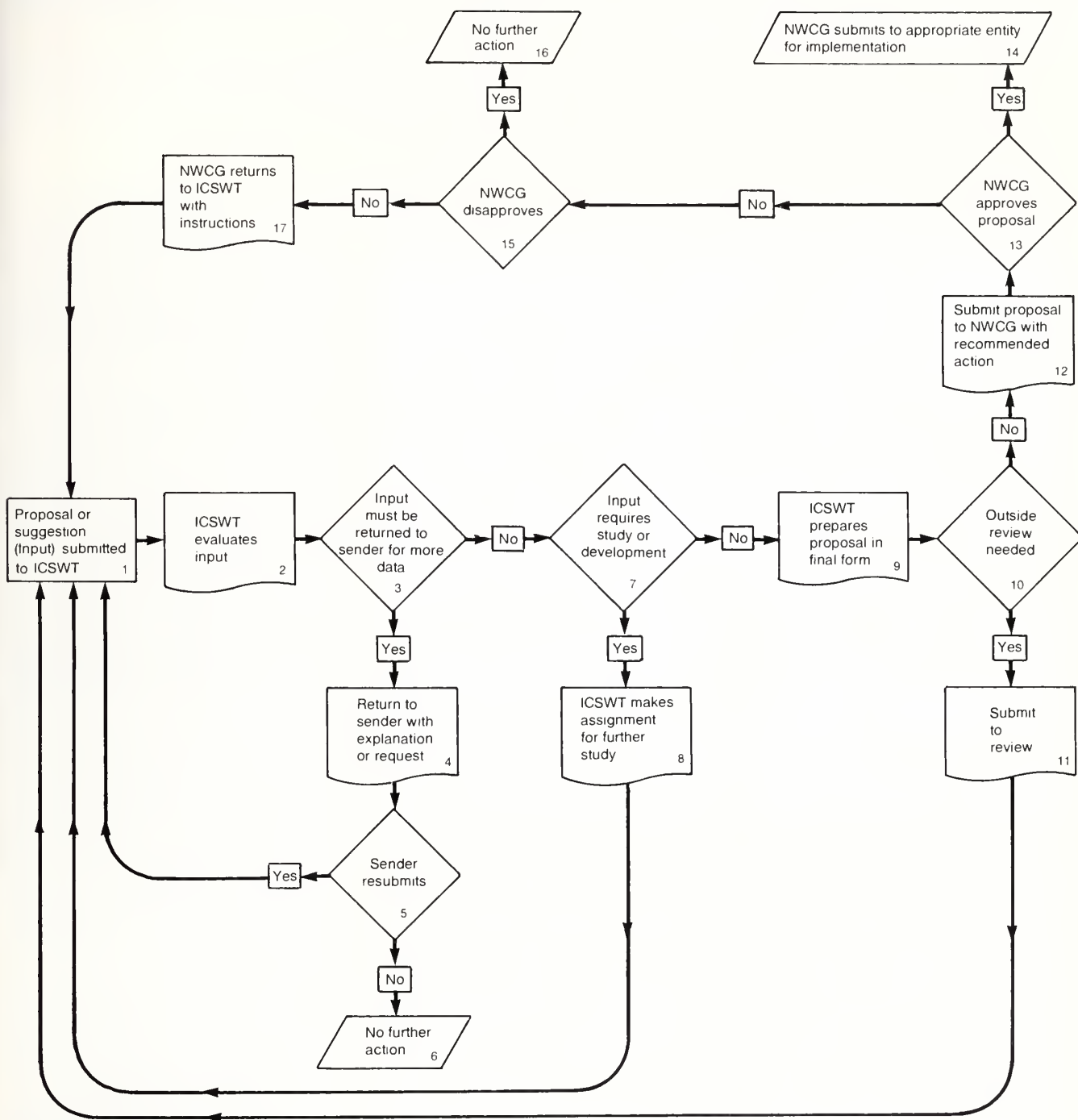Sender resubmits 5

Yes

No

No further action 6

Figure 1—*Process used by the ICS working team (ICSWT) for considering suggestions for modifying the system.*

Fire Division Under ICS

David L. Hanson

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As it is becoming more widely used across the Nation, the Incident Command System (ICS) has left some of us in the wildland fire protection agencies with questions about how fire incidents are intended to be broken down into manage able geographic areas.

Divisions, as they are described in ICS, are intended to represent a geographical area for the purpose of organizing and directing fire suppression resources on wildland fire incidents. Some of the concerns that have been expressed about the use of ICS divisions include a belief that the division may encompass too large a geographical area and that some additional smaller geographical area designator may be needed. There has also been a reluctance to use ICS divisions on initial attack operations or on small multioperational period fires because of the lack of readily available qualified division supervisors.

Some of these concerns can be addressed by accepting the idea that using the ICS term "division" to refer to geographical areas on your fire incident does not necessarily indicate that the division covers a large area or has a large number of resources or even that a person qualified as a division supervisor is commanding that division. The

Initial Attack Incident Commander who separates an incident into two or more divisions, regardless of the size of the incident, has made an important step towards implementing ICS. If the incident escalates in size and complexity the incident commander is in a position to expand the organization accordingly.

Even on a relatively small incident, the Initial Attack Incident Commander, with one crew, can take one side of the fire and call it division A, assigning a second crew to take the other side of the fire, division B. There is no real need to assign someone qualified as a division supervisor to command a division until or unless the personnel and resources required by that division become extensive enough to make such an assignment necessary.

Another concern in our adjustment to the use of divisions in ICS is the loss of the lesser geographical area designator, the sector, that many of us were accustomed to in our previously used incident-management system, the Large Fire Organization (LFO). Perhaps it would be helpful to consider that in the old LFO, even when a sector was used within a division, oftentimes further informal unstructured geographical separations were-

employed within the sector. For example, the sector boss would have one crew boss cover from point A to point B and another crew boss cover from point B to point C and so on.

It is also perfectly acceptable within ICS to use divisions that incorporate other lesser geographical areas as designated by the division supervisor. For example, the division supervisor on a major incident may decide that he needs help in supervising fire control line-construction in part of the division. He delegates that task to a person qualified as task force leader from among the division's assigned single resource bosses.

It is important to realize that ICS should not be seen as limiting what we do in dividing or organizing our fires. Instead, ICS should be seen as a basic framework for organization that can be applied to initial attack and, if necessary, systematically expanded to handle extended attack or even major incidents.

Sharing experiences, problems, and solutions among all the users of ICS still offers the promise that all of us with a fire protection mission can improve our own operational abilities as well as our ability to work more effectively together. ∎

ICS Qualifications

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In 1984 the National Wildfire Coordinating Group's (NWCG) qualification and certification working team, now the Incident Command System (ICS) working team, published the Wildland Fire Qualification Guide *(1)*. This guide includes the NWCG requirements for minimum training, experience, and physical fitness for positions in the ICS. The result of these common standards has been the formation of a nationwide pool of wildland firefighting personnel who are qualified to perform fire suppression jobs for which they have been certified. Some agencies have supplemented the guide with agency requirements for their own use.

After the production of the qualification guide, an obvious next step was to assist managers by developing a data management system to record and track information necessary for qualifications. The ICS working team described the needed criteria, and the Forest Service agreed to develop, test, and recommend such a system to the NWCG. The result was an automated recordkeeping system for wildland fire qualifications that has been accepted by NWCG (fig. 1). The program resides at the Ft. Collins Computer Center (FCCC).

Basically the program is a data management system for personnel involved in wildland firefighting. Qualifications are determined by agency managers rather than by computer analysis. The initial transition to ICS is accomplished by entering the position(s) that the individual has been

Figure 1—*The automated recordkeeping system for wildland fire qualifications helps ensure that qualified personnel will be available when needed.*

qualified to perform in, based upon a local management review of his or her training and experience. Target positions for future qualification can be entered as well as subsequent training and experience. Planned training, special skills, or other information can be entered in the remarks section. The program has the capability to create short history files suitable for downloading to microcomputers for use in locally developed applications.

The information is transferred from the data entry form (form 320) to a computer data file format by whatever

data entry system is available to the user. Forest Service users can use Forms Entry Systems (FES) on Data General equipment. Other users would have to find a means on their local system that could communicate the resulting data file to FCCC for processing by the program or use data entry facilities available at FCCC.

Agencies or units interested in the system should order the needed materials from the Boise Interagency Fire Center warehouse. There are four items available: User's Guide for the ADP System, catalog #1516; PMS

Form 320 for manually recording and storing data, #1517; red cards with the headings preprinted for typewriter or manual use, #1518; and blank red cards for computer printer use, #1519. The Wildland Fire Qualifications Guide, PMS 310-1, which is necessary for determining national level qualifications, is #1414.

This program is one method of managing ICS data currently available to any user. Individual agencies or units may have or develop other methods to better meet their particular needs. Local agency managers may want to contact their supervisor to determine the best method available to them. ■

Literature Cited

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General Services Administration Supports Firefighters

The General Services Administration (GSA) has been a member of the wildlife suppression community since 1956. Through its Federal Supply Service (FSS), GSA contracts for wildfire suppression equipment and supplies needed to help protect the Nation's forest and grassland resources from the ravages of fire. FSS considers its wildfire suppression equipment program second only to national security in order of priority.

An FSS catalog, "Wildfire Suppression Equipment and Supplies," is the basic supply publication for use by the United States Forest Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, and other Forest Service certified participants in the Governmentwide program. Because GSA complies with all regulations governing the competitive purchasing of items, customer agencies may, in compliance with their internal agency procedures, order directly from GSA.

Easy acquisition of firefighting equipment and supplies stocked in GSA warehouses is the first step in GSA's assistance to firefighters. In the event there is any problem with a GSA stock item order, the next important form of assistance is the followthrough provided—that's where GSA's Discrepancy Reports Center comes into play.

At the time catalog orders are received, the merchandise should immediately be checked for visible irregularities such as overages, shortages, or damage. Any carrier abnormalities should be stated on the carrier's delivery form with the carrier's representative acknowledging the same. A report of discrepancies should be sent immediately on Standard Form 361 for carrier discrepancies and on Standard Form 364 for shipper discrepancies (GSA warehouse or vendor) to:

Discrepancy Reports Center
1500 E. Bannister Road
Kansas City, MO 64131
Quality complaints are handled

by the GSA Quality Complaint Hotline on FTS 557–1368 (703) 577–1368. Regulatory information regarding discrepancy reporting is detailed in FPMR 101-26.8, "Discrepancies or Deficiencies in GSA or DoD Shipments, Material, or Billings."

Additionally, customer service officers in the GSA regional offices across the country are available to assist firefighters in obtaining wildfire suppression equipment and supplies (telephone numbers and addresses are in the "GSA Supply Catalog"). Discrepancy Reports Center specialists are on hand to assist with order discrepancies on FTS 926–7447 or Autovon 465–7447.

The natural environment is precious, and GSA's Federal Supply Service stands ready to help maintain it.

Louise Nyland
General Services Administration
Washington, DC

Wildfire Prevention: New Perspectives on an Old Problem

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Because of certain social trends occurring in the United States and also because of some relatively new administrative requirements, our needs for fire prevention information are changing. I will describe our current system of information gathering, pointing out some of the strengths and weaknesses of the system, and then discuss the new demands for fire prevention information growing out of social change and administrative mandates in the United States.

Most of our current fire prevention information, like yours, comes from our individual fire reports. The key elements from a prevention standpoint are: statistical cause, general cause, specific cause, and class of people. Statistical causes, which are used by all protection agencies in the United States, are reported annually in our "Wildfire Statistics." General cause is defined as the general type of land use activity responsible for a fire, and specific cause as the specific activity or ignition source causing the fire. This cause classification system, though amended occasionally, has been used by the Forest Service for 80 years and appears on State and Federal fire reports in varying formats. When combined with location, size class, and acreage burned information, it not only gives us an idea of what our problems are but where and how big they are. Based on this information, our land managers select ap-

propriate fire prevention programs and allocate resources to solve their wildfire problems. By monitoring trends in fire causes, they also use the information to evaluate the impacts of their programs.

Although managers find this process workable, it still can be improved. No matter how much statistical wizardry we scientists perform on the data, we can't make it any better. Although we take what is on the forms and transform it into impressive graphs and charts for our user groups, what comes in must go out. Therefore, if the data coming in are inaccurate what goes out is inaccurate. One of the reasons for inaccurate data is the design of the reporting system; the other part is due to our assessment of fire causes at the fire scene.

First, let's look at the reporting system itself. Ours follows a progression of "add on" information. Eighty years ago, we started with eight basic causes. These apparently were inadequate for over the years new cate-

gories (general cause, specific cause, and class-of-people) were added to pinpoint both the cause and who started the fire.

Although to our credit we've maintained consistency in our fire-cause reporting system, unfortunately we've also created categories that are repetitious and not mutually exclusive. As a result, we can easily have multiple classification schemes for a given fire cause, making it difficult to determine from fire-report data the actual cause and person responsible for a particular wildfire. For example, a dump fire set by one or more persons is reported in the Northeastern United States using seven different cause and class-of-people combinations (table 1). What seems simple to record turns out to be complex!

Compounding the problem of overlapping or non-mutually exclusive categories is the broad and repetitious nature of our fire-cause reporting system.

Our system also lacks any way for reporters to indicate the certainty

Table 1—*Classification of dump fires in the Northeastern United States*

Statistical cause	General cause	Specific cause	Class-of-people
1. Incendiary	Incendiary	Burning dump	Local permanent
2. Incendiary	Incendiary	Grudge	Local permanent
3. Debris burn	Other	Trash burning	Visitor
4. Debris burn	Resident	Burning dump	Local permanent
5. Debris burn	Incendiary	Trash burning	Local permanent
6. Debris burn	Other	Burning dump	Local permanent
7. Miscellaneous	Resident	Burning dump	Local permanent

of their fire-cause data. That is, once entered on a fire report form, reliable causes are indistinguishable from unreliable ones. With no "unknown" category available, an unknown cause is typically classified as a smoking, incendiary, or miscellaneous wildfire. Because reporters cannot indicate the reliability of fire causes, the accuracy of fire-cause data is often questionable, leading to erroneous assumptions about the fire prevention problems.

Even if our reporting system were perfect, we would still have the difficulty of assessing the cause of a wildfire at the fire scene. What it boils down to is that we often don't do a good job of fire-cause investigation. And, if we don't do a good job investigating, what goes on the fire reports and into our data files isn't very good either.

So what are we doing about all of this? It wasn't too long ago that the building block system was proposed to replace our traditional system. This new system included the:

• *Form of heat energy that ignited the fire:* for example, flames, sparks, and hot surfaces from a variety of sources.

• *Reporter's certainty of heat of ignition.*

• *Equipment involved in starting the fire:* e.g., cooking equipment, electrical equipment, woodland equipment.

• *Material first ignited:* grass, leaves, paper, hay, etc.

• *Ignition factor:* how the form of heat energy and the material first ignited combined to start a wildfire—for example, incendiarism, misuse of equipment, mechanical failure, or design deficiency.

This system also included the type of person responsible for fires, the person's age and sex, and the primary activity the person was involved in when the fire started. Although the idea was good, it wasn't widely accepted because it was too cumbersome to use (25 pages of categories to choose from!) and broke too much with tradition.

The Forest Service decided to compromise. Our new fire report contains only statistical causes: debris burning, campfires, incendiary, railroads, smoking, equipment use, children, miscellaneous, and lightning. We're back to where we started in 1905! These are reported uniformly across the Nation. The system is obviously simple to use and historically compatible with previous fire report data. If, however, managers want more detailed fire prevention information for their administrative units, they can also use the building block system contained on a supplemental fire report form.

Finally, to improve the quality of the data, fire-cause investigation is being emphasized nationwide. This is, in part, a reaction to the in-

crease in arson in the United States. Nationally, it's the number one cause of wildfires. To get a better handle on the magnitude of this problem, the wildland fire community has decided to improve its investigative skills. With better investigative work comes better wildfire cause data.

What I've just described is our current system of reporting data that is useful to the fire prevention community. And it's a traditional system. We use the information, as we have for decades, to define our fire prevention problems in terms of number of fires, their causes, acreage burned, and so forth. And, if we're asked to demonstrate our achievements, we point to the increase or decrease in human-caused fires over time. But in our day and age, this is no longer adequate.

With tightening budgets, cutbacks in our management programs and personnel, and mandates from Congress to demonstrate the cost effectiveness of our fire management activities, the Forest Service has implemented a national system for analyzing, from an economic standpoint, fire management programs.

The system provides a formal process for evaluating the efficiency and effectiveness of fire programs at the national and regional levels.

When I say "fire programs," I mean total fire management programs which include wildfire-prevention. In the past, we've

tended to separate prevention from the rest of the fire picture. It was always an isolated event outside of the mainstream. Now, we're looking at the complete picture, including prevention, presuppression, and suppression activities. This brings up a number of questions about the economics of fire prevention programs. For instance:

● How much do our fire prevention programs cost us and what do they "buy" us in terms of number of wildfires?

● What is an efficient program level?

● What is an efficient budget level?

● How many fires do these efficient program and budget levels generate and what's the cost plus net value change of these fires?

● How does fire prevention interact with the rest of fire management? If we reduce the number of fires, how does that affect our suppression forces?

These are some of the questions that those of us in fire prevention are now asking and are required to ask. We're no longer looking at just an increase or decrease in the number of fires but, in addition, the costs and effects of these changes.

So, what kinds of additional prevention information do we need?

Initially we need to document:

1. The kinds of educational, engineering, and law enforcement activities we perform.
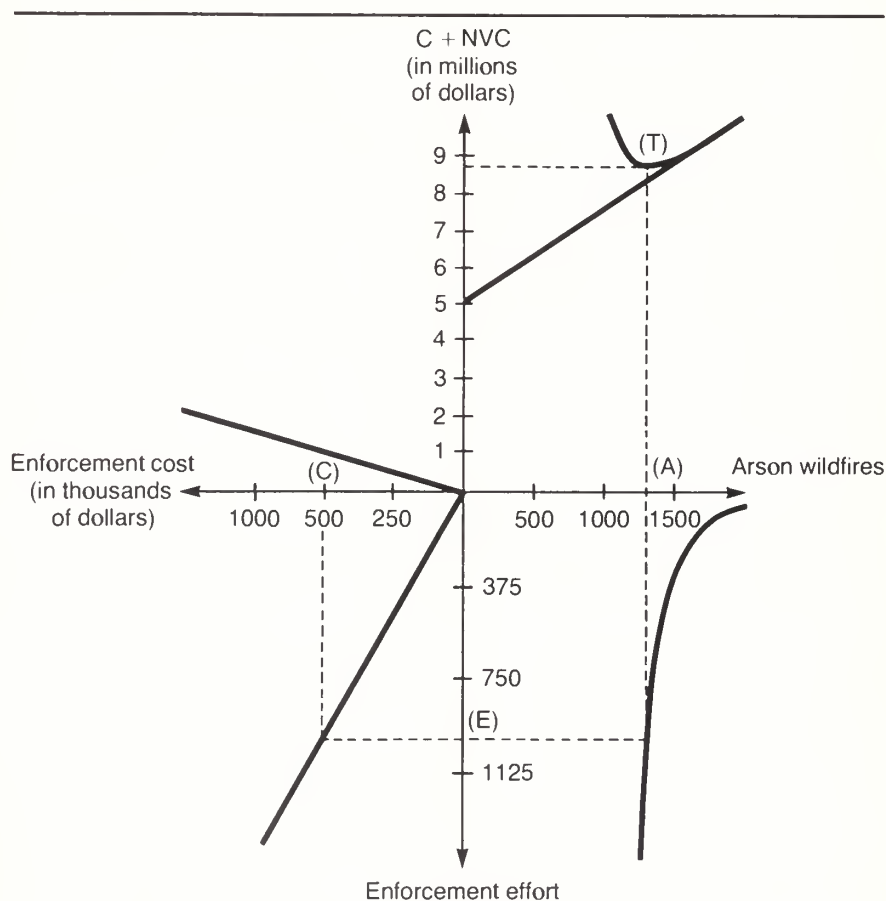

Figure 1—*Nomogram for the State of Arkansas depicting the relationship between the law enforcement program, the number of arson wildfires, and the economic impact of those fires.*

2. How much of each of those activities we perform.

3. How much these activities cost, both fixed and variable costs.

In addition to our suppression costs, we also need to know the net value change in our wildland resources resulting from human-caused wildfires.

All of this information can then be combined into one map or set of nomograms to show, for a particular administrative unit, what our most efficient level of program operation is and what the consequences of that program might be. Figure 1 is an example. We've developed this diagram for the State

of Arkansas. This figure depicts only one aspect of their fire prevention program—law enforcement activities targeted at arson wildfires.

The axis pointing downward reflects the quantity or amount of law enforcement activity (in this case the number of prosecutions, convictions, and settlements) in Arkansas; the axis pointing to the left depicts the cost of these enforcement activities. The axis pointing to the right indicates the number of arson wildfires that can occur in Arkansas, the axis pointing upward shows the suppression costs (C) plus net value changes (NVC) due to these fires.

The lines of this graph represent relationships. The diagonal line in the lower left quadrant, for example, represents the relations between law enforcement activities and the costs of those activities. This line shows that as law enforcement activities increase, the costs of those activities will also increase. We're assuming for the purposes of this exercise that each unit of enforcement, i.e., each prosecution, conviction, or settlement, costs Arkansas $500. The curved line in the lower right quadrant indicates that at low levels of law enforcement effort, Arkansas can expect a high number of arson fires, but as the State increases its enforcement efforts, it can expect a gradual decrease in these fires. Finally, the straight line in the upper right quadrant indicates that as the number

of arson fires increases, the C + NVC will increase correspondingly. The curved line in this quadrant reflects Arkansas' total fire management costs, including not only the C + NVC caused by arson wildfires but also the State's prevention (law enforcement) costs.

So, how would a manager in Arkansas use this diagram? Let's assume that the manager is aiming to undertake 1,000 prosecutions, convictions, and settlements against arsonists next year. That level of law enforcement effort (E), could be expected to cost about $500,000 (C). (Follow the dashed line from letter E to letter C.) Given those 1,000 units of enforcement (E), 1,300 arson wildfires (A) could be expected. (Follow the dashed line from letter E to letter A.) The total fire management costs (T), including prevention (law enforcement) costs, would be about $8.7 million—the most efficient level of operation (the lowest point of the curve). (Follow the dashed line from letter A to letter T and over to the C + NVC axis.)

What if the manager's prevention budget were cut in half, from $500,000 to $250,000? What effects would that have? With a $250,000 prevention budget (Enforcement Cost axis), the manager could afford about 500 units of enforcement (i.e., 500 prosecutions, convictions, and settlements). With this reduced level of prevention activity, about 1,400 arson wildfires could be expected.

The C + NVC due to these additional fires would be $8.5 million, and the total fire management cost would add up to $8.8 million (C + NVC + enforcement costs).

There's a lot more that we can do with this diagram from an analysis standpoint, but I believe you can get an idea of where we are headed with our analyses of fire prevention programs. Although this is a simplistic model, we're hoping to improve it greatly by collecting cost and prevention activity data for each component of fire prevention so that we can more adequately reflect what's happening in the real world. If we can do that, then we can turn this into an operationally useful system.

Of course, no matter how sophisticated we get, we can't do our job well unless we have good fire prevention information. Some of that valuable information will come from better reporting systems and some from better fire cause investigation. And with improved quality of information, we scientists will be able to give our clients better products to work with. ■

The True Story of the Pulaski Fire Tool

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The nickel-plated pulaski looks as good as new in its glass-fronted Collins Tool Company display case at the Smithsonian Museum of Arts and Industry in Washington, DC. Surrounded by equally shiny cutting tools of all description, the pulaski was first put on display at the Nation's Centennial Exhibit in Philadelphia in 1876.

Conventional wisdom holds that the pulaski fire tool was invented by Edward C. "Big Ed" Pulaski in the second decade of the 20th century. Ed Pulaski, a descendant of American Revolution hero Casimir Pulaski, was a hero of the Great Idaho Fire of 1910, leading his crew to safety when they became imperiled. He was also one of a group of ranger tinkerers who struggled to solve the equipment problems of the budding forestry profession. However, the pulaski tool on display at the Smithsonian must have been made when Big Ed was no more than 6 years old!

In the early days of forestry in this country, fire tools were whatever happened to be available. The earliest methods of firefighting were confined mostly to "knocking down" or "beating out" the flames, and the tools used in the job were simple and primitive. The beating out, when such an approach was possible, was often accomplished with a coat, slicker, wet sack, or even a saddle blanket. A commonly used tool was a pine bough cut on arrival at the fire edge (4).

Soon farming and logging tools, available at general and hardware stores, came into use. These included the shovel, ax, hoe, and rake—all basic hand tools developed over centuries of manual labor. Even after firefighting became an important function of forestry agencies, these tools were accepted as they were, wherever they could be picked up, and little thought was given to size, weight, and balance. There appears to be no record of the use of the Collins Tool Company pulaski for fire control. Most likely, it was sold to farmers for land clearing and may have been forgotten by the late 1800's (2).

With the advent of the USDA Forest Service and State forestry organizations, a generation of "ranger inventors" and tinkerers began to emerge. It became apparent that careful selection and modification was essential for efficient work and labor conservation. In the early days when almost everybody and everything had to travel by horseback transportation was a particular problem. For years foresters worked on the idea of combination tools. Most of the attempts were built in home workshops, and most "went with the wind." Two important survivors, now in general use, are the McLeod tool, a sturdy combination of rake and hoe, and the combination of ax and mattock. The McLeod was probably the first fire tool to be developed. It was designed in 1905 by Ranger Malcolm McLeod of the Sierra National Forest.

Who first invented the ax-hoe combination and used it for firefighting is a matter of minor dispute. Earle P.

Dudly claims to have had a pulaski-like tool made by having a lightweight mining pick modified by a local blacksmith. He says he used the tool for firefighting in the USDA Forest Service's Northern Rocky Mountain Region in 1907. Dudly was well acquainted with Ed Pulaski, and the two had discussed fire tools.

Another account of the origin of the pulaski is that William G. Weigle, supervisor of the Coeur d'Alene National Forest, thought of the idea—but not for firefighting (5). Rangers Ed Pulaski and Joe Halm worked under him (all three became heroes of the Great Idaho Fire) at Wallace, ID, then headquarters for the Coeur d'Alene National Forest. At that time, plans were being made for some experimental reforestation, including the planting, pine seedlings. As Supervisor Weigle planned the job, he decided a new tool was needed to help with the planting as well as other forestry work. He decided on a combination of ax, mattock, and shovel. One day in late 1910 or 1911, Weigle sent Rangers Joe Halm and Ed Holcomb to Pulaski's home blacksmith shop to turn out a combination tool that might replace the mattock that was then in common use for tree planting. Halm, with Holcomb helping, cut one blade off a double-bitted ax, then welded a mattock hoe on at right angles to the former blade position. He then drilled a hole in an old shovel and attached it to the ax-mattock piece by means of a wing bolt, placing it so the user could sink the shovel into the earth by ap-

plying foot pressure to the mattock blade.

The rather awkward device was not a success as a planting tool. Probably the whole idea would have been abandoned had not Ranger Pulaski been fascinated with the possibilities of the tool. He kept using it, experimenting with it, and improving it. He soon discovered that the bolted-on shovel was awkward and unsatisfactory. He abandoned the shovel part and also lengthened and reshaped the ax and mattock blades. It is too bad Pulaski did not know about the Collins Tool pulaski—it would have saved him a lot of time. Nevertheless, by 1913 Pulaski had succeeded in making a well-balanced tool with a sharp ax on one side and a mattock or grubbing blade on the other.

Pulaski use now spread throughout the Rocky Mountain region. However, it was used not for tree planting but for fire control. By 1920 the demand was so great that a commercial tool company was asked to handle production.

Although the pulaski went into widespread use in the Rockies in the 1920's, it saw little or no use in other areas. Prior to 1931 the USDA Forest Service had no good internal method for handling equipment development and promotion. Most new equipment ideas were introduced and discussed at the regular Western Forestry and Conservation Association meetings (3, 7).

By the mid 1930's, with the advent of the CCC, fire tools began to prolif-

Figure 1—*Firefighter using pulaski on Plume Creek fire in the Kaniksu National Forest in Idaho.*

erate, and the USDA Forest Service sought to standardize tools rather than develop new ones. It was at an equipment standardization conference at Spokane in 1936 that the pulaski tool was proposed for national distribution. The conference instructed the USDA Forest Service's Region 1 to develop and further test a prototype suitable for servicewide use (6, 8).

Since "Big Ed's" day the pulaski, as well as other fire tools, has undergone continual improvement. Pulaski development is an ongoing ef-

fort at the USDA Forest Service's Missoula Equipment Development Center. Careful engineering study, design, and testing have resulted in standards of shape, weight, balance, and quality (fig. 1).

Although Ed Pulaski may not have invented the first fire tool put into general use or even first thought of the tool that bears his name, he did develop, improve, and popularize the pulaski. The General Services Administration now puts out bids for more than 35,000 new pulaskis each

year—a long way from the prototype so laboriously made in Ranger Pulaski's home blacksmith shop *(1)*.

■

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Evaluating Arson-Caused Forest Fires in Wisconsin, 1982–85

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Forest fire arson is a problem of some concern for forest fire control people in Wisconsin. In the past 4 years, 567 forest fires were intentionally set. Wisconsin forestry officials consider this number to be entirely too high, especially considering that the figure covers only those lands protected by the Department of Natural Resources (DNR), or roughly one-half of the State land area. Fire responsibility for the remainder of the State lies with either the township or municipal government.

Forest fire arson, for purposes of this article, consists of fires willfully set by anyone to burn vegetation or property not owned or controlled by the fire setter and without the consent of the owner or owner's agent (*1*).

Wisconsin forest rangers reported 567 arson wildfires in the period from 1982 through 1985. These fires were sorted as to degree of certainty of fire cause according to the following criteria (*2*):

1. *Certain*—Form of cause is established by admission, statement of reliable witness, or physical evidence. This category is intended to cover cases where cause is established beyond doubt.
2. *Reasonably certain*—Cause is established by strong circumstantial evidence. This category covers cases where cause is reasonably certain, but witness statements or physical evidence may not be conclusive.
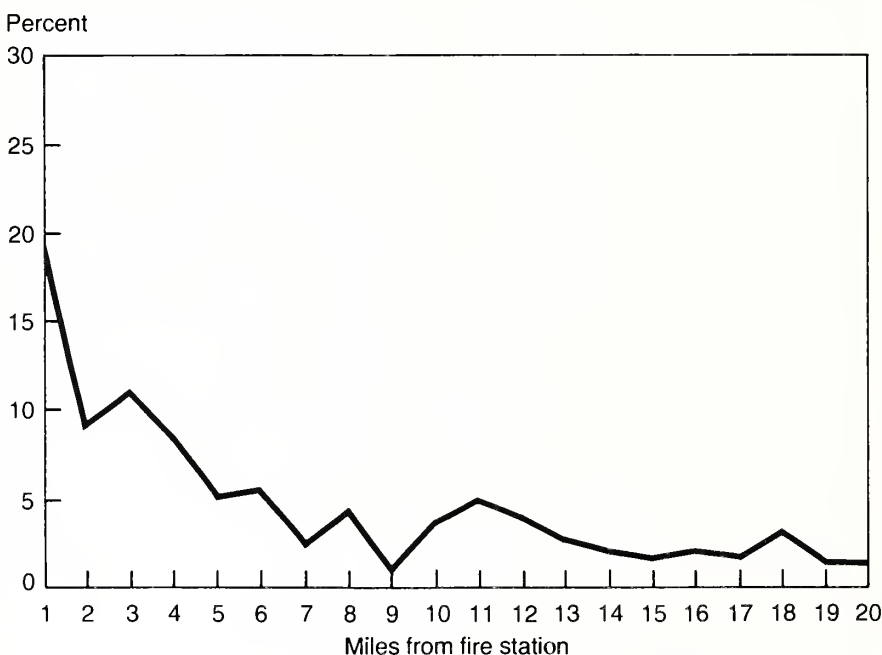

Figure 1—*Distance from fire station of arson-caused forest fires in Wisconsin, 1982– 85.*

3. *Less probable*—Form of ignition is established by weak circumstantial evidence, by process of elimination, or by fire history of the area and experienced judgment of the investigator.
4. *Undetermined*—No definite clues or several probable forms of ignition or fire not investigated.

Only fires that were coded *certain* or *reasonably certain* were selected for the study. Three hundred sixty- one records (64 percent) were coded *certain* or *reasonably certain* by the investigating officers. The persons responsible for 54 arson fires were also identified, and some

demographic data were gleaned from their records.

Of the 361 records examined, 201 or 55 percent indicated that the fires were set within 6 miles of the responding fire station. Almost 19 percent of the arsonists set fires within 1 mile of the station (fig. 1). Since most of our ranger stations are located in rural communities this information may indicate that the fire setters live in or near town.

The majority of the arson fires (51.7 percent) were discovered by local residents. This finding is consistent with the percentage of all fires discovered by the local citi-
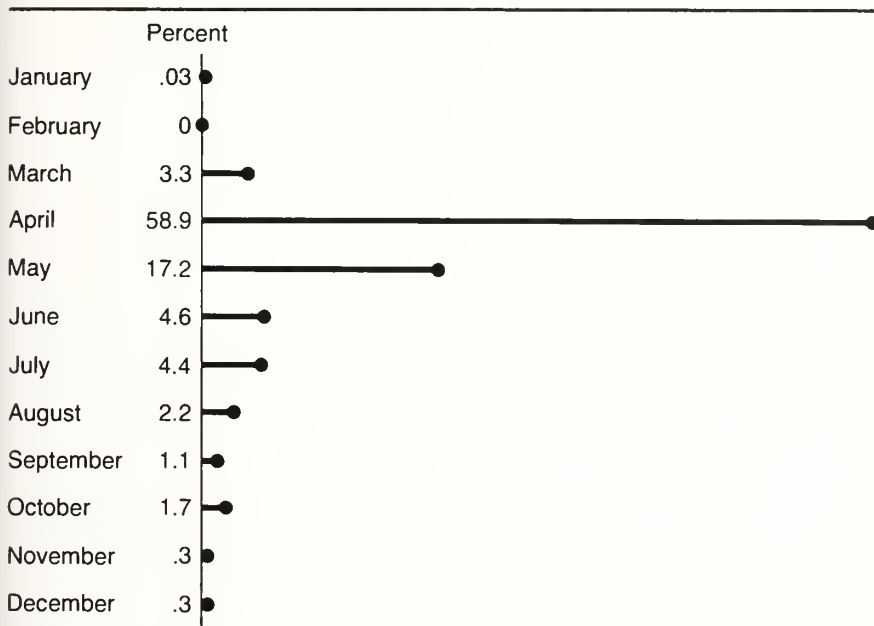
Figure 2—*Arson-caused fires in Wisconsin according to month, 1982–85.*

zenry as opposed to lookout towers, aircraft, or other means.

Almost 60 percent of the incendiary fires occurred in April, and by the end of May, more than 75 percent of the State's incendiary fires had been set (fig. 2). There appear to be two rather significant peaks. One is an 11-day period from April 24 through May 4 when 27 percent of this type arson fires were set. Another peak occurred during a 9-day period from April 9 to April 17, when 19 percent of the fires were set.

April and May are Wisconsin's busiest forest fire months both in numbers of fires and acres lost. Perhaps several factors, such as frequent fire runs by the fire agencies, ease of ignition of forest fuels at this time of year, and the balminess of the weather, combine to stimulate fire setting behavior.

The day of the week that the most fires occurred was somewhat surprising. Sunday ranked highest, with an average of 21 percent occurring on that day; 35 percent occurred on Saturday or Sunday. Forty- eight percent of all the fires occurred on the first 3 days of the week—Monday (14.8), Tuesday (18.4), and Wednesday (14.8). Thursday and Friday ranked the lowest at 9.7 and 7.5 percent, respectively (fig. 3).

Arson fires seem to pick up on Saturdays, peak on Sunday, and then generally decrease to the low of 7.5 percent on Friday. In much of the DNR's jurisdiction, the burning of trash on Sundays is prohibited, following the premise that careless campers, hikers, sightseers, and other recreationists would keep the firefighting forces busy. It appears that, with the demonstrated peak of arson activity on Sundays, the banning of trash burning may be even more justified.

The pattern for time of day for fire starts is interesting. Fire setting activity seems to begin at about 1200 hours, peaks at 1500 hours, decreases to a low point at 1700 hours, and then rises again to a lesser peak at 1900 hours. Fire setting then decreases to a low point at 2200 hours, at which time over
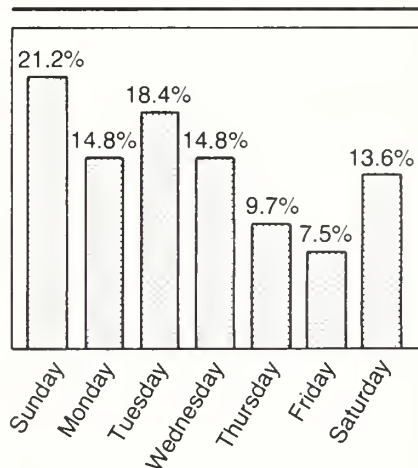

Figure 3—*Arson-caused fires in Wisconsin according to day of the week, 1982–85.*
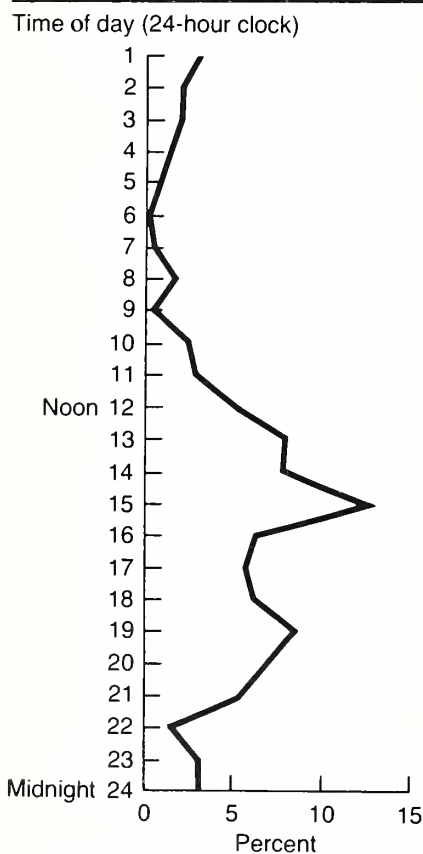
Time of day (24-hour clock)

Figure 4—*Arson-caused fires in Wisconsin according to time of day, 1982–85.*

90 percent of the incendiary fires have been set (fig. 4). Perhaps the dip in the late afternoon reflects some chores that have to be accomplished and time out for the evening meal. The increased early evening activity may indicate increased idle time after the evening meal or a desire to re-create the emo-tional "high" attained by the afternoon arson or perhaps both. This daytime fire setting pattern is contrary to the general belief the public has that arson is a crime of the night. Our experience shows that wildland arson occurs in broad daylight during the most dangerous burning time, when our firefighting forces are busiest with accidental fires and when the set fires could potentially do the most destruction.

Another myth was brought down with this study. It had generally been felt that State-owned lands were targets for the arsonists. This proved not to be the case. Private landowners suffered the worst of the attacks—more than 57 percent of the arson fires occurred on private land. Federal lands were singled out next with 15.3 percent, then State lands with 7.4 percent. The remaining fires were on county, municipal, and various highway rights-of-way (fig. 5).

Of the 361 records that were studied, persons responsible for 54 fires were identified. The demographics didn't produce any surprises: 97 percent were male and 63 percent were 25 years of age and under. However, 24 percent were between 38 and 56 years old. There seem to be two main age groups involved in fire setting: 25 and under and the late 30's to early 50's (fig. 6 and 7).

The people that set fires are generally not transients, vacationers, or summer people. Eighty percent were identified as permanent residents, the group most likely to be

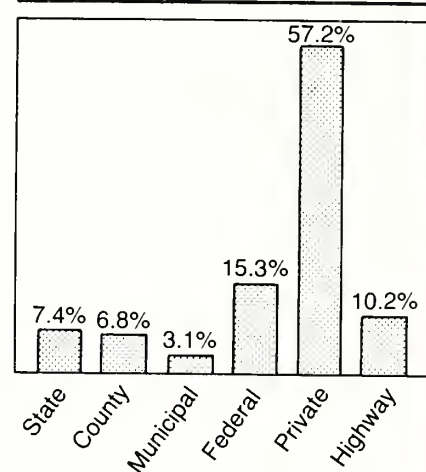Figure 5—*Ownership of land where arson-caused forest fires originated, 1982–85.*
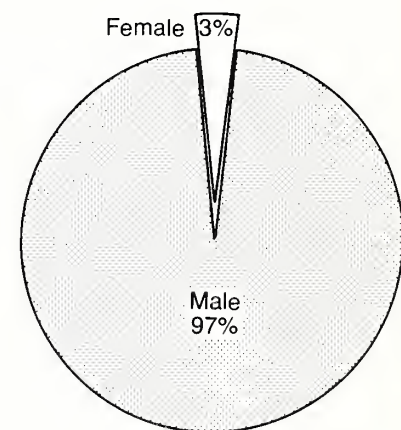

Figure 6—*Sex of known forest fire arsonists in Wisconsin, 1982–85.*

injured from a forest fire gone awry (fig. 8).

In conclusion, in Wisconsin arson forest fires are more likely to occur during two short periods in April
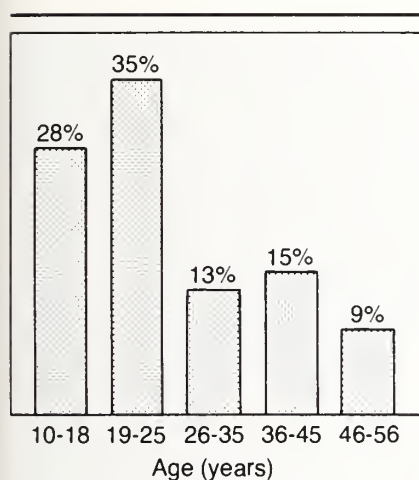
Figure 7—*Age distribution of known forest fire arsonists in Wisconsin, 1982–85.*

Figure 8—*Residency status of known forest fire arsonists in Wisconsin, 1982–85.*

and May. During these two periods increased vigilance may well be warranted and productive. Fires tend to be set during the day in early afternoon, on private lands within 6 miles of the ranger station. The perpetrator will probably be male, either less than 25 or between 38 and 55 years old. His activity will be most likely on Sundays or Saturdays.

Perhaps the information provided by this study, along with personal knowledge of local conditions, will aid in setting up patrol routes and surveillance procedures that will result in fewer arson fires and the apprehension of arson suspects. ■

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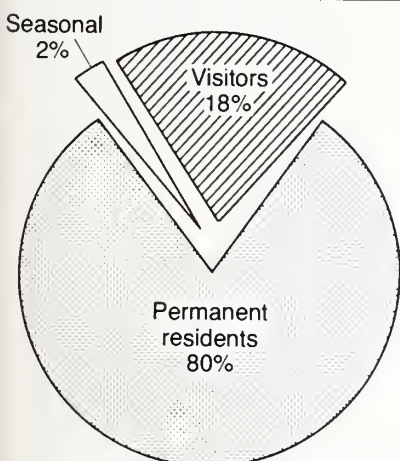
Wildland Firefighters Personal Protection Gear

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Introduction

Wildland fires trapped an estimated 200 firefighters during the 1985 fire season. These entrapments, and the role fire shelters and other personal protective equipment played in saving lives and preventing serious burn injuries, have stimulated great interest. The purpose of this article is to provide field people with additional information on this vital safety equipment.

Fire shelters, special clothing, and other protective equipment exist today because 28 years ago, after an analysis of casualty-causing fires, the Forest Service committed itself to developing effective personal protective gear for wildland firefighters. The Missoula Equipment Development Center (MEDC) has spearheaded this effort over the years and continues to improve the items that make up the firefighter's personal protective system.

Personal Protective System

The basic components of the system include:
- Fire shelter
- Hardhat
- Goggles
- Flame-resistant shirts and jeans
- Leather boots and wool socks

The fire shelter provides protection during fire entrapment and protects vulnerable airways and lungs, which the other components of the system cannot do. We wrote about the fire shelter in the last issue of Fire Management Notes, so here we will focus on the other items of personal protective equipment (PPE).

Properly equipped wildland firefighter in the process of deploying fire shelter.

Together, these items protect fire-fighters from thermal and other job hazards while they work. Several key requirements guide the Missoula Center's development and test work on PPE. Each item must protect the wearer and not contribute to fatigue or injury by premature failure. In addition, it must be lightweight, functional, durable, comfortable, and economical. With regard to comfort, heat stress is a prime concern. When we speak of economical equipment, we don't necessarily mean the lowest in price. We look at an item's life-cycle cost, not just acquisition cost. A good example is flame-resistant clothing. A garment that costs twice as much as another may still be more economical if it outwears the less expensive garment by a factor of more than two to one.

Hardhat

With the possible exception of the fire shelter, the hardhat is the most important piece of wildland firefighting safety equipment. Hardhats have saved many lives and prevented serious injuries by protecting the wearer against falling trees, limbs, and rolling rocks.

The literature indicates that approximately 15 percent of the body's heat is lost through the head, so hardhats, which are cooler and lighter in weight, are preferred over helmets designed for structural firefighting. Special clips are added to attach goggles and night firefight-ing headlamps. As wildland fire-fighters confront more fires in areas where there are structures and associated electrical hazards, class B plastic hardhats, which provide electrical hazard protection, are preferred.

Goggles

A study conducted from 1967 through 1971 showed that eye injuries accounted for about 7 percent of all fire suppression injuries. Dust, smoke, brush and branches, and hot substances cause most eye injuries.

Thus goggles are an important component of the PPE system. Fire-fighters are dissatisfied with the goggles now available. A recent survey indicated comfortable goggles that won't fog or scratch are one of the firefighter's greatest needs. We hope to begin a project aimed at finding better fog-free goggles for forest workers that will meet firefighting needs.

Development of Flame-Resistant Clothing

Work on flame-resistant clothing began in 1958 concurrently with fire shelter development. The objective was to design garments that would offer firefighters protection (1) against flames, falling embers, and coals; (2) when dashing for safety to avoid entrapment; (3) during entrapment without a fire shelter and added protection within a shel-ter; and (4) if involved in an aircraft accident.

Extensive use of flame-resistant shirts began in 1962 with the introduction of flame-retardant treated (FRT) cotton shirts. FRT cotton trousers were field evaluated along with shirts. But trousers are subject to greater wear, and FRT cotton had poor durability, so flame-resistant trousers were impractical until Nomex® fabrics became available in the early 1970's.

After using orange FRT cotton shirts for several years, we switched to yellow shirts in the late 1960's. Studies on PPE for urban fire-fighters showed yellow to be more visible in dark and smokey environments. Also, there were several incidents in which the orange shirts were mistaken for flames and aircraft dropped fire retardant on crews on the line.

Firefighters wore FRT cotton shirts for about 10 years. Then in 1973, after many years of field evaluation, we adopted flame-resistant Nomex® for shirts. Nomex® is woven from a nylon-type fiber designed to withstand high temperatures. Like most fabrics, Nomex® burns if exposed to flame, but unlike the others, it stops burning when removed from the flame. Instead of melting or burning to ash, it forms a char that continues to help protect the skin. In 1974, Nomex® pants became available. We've worked to improve these garments over the years.

Flame-Resistant Shirt

MEDC specialists worked with the producer of Nomex® fiber and several fabric weavers for 3 years to develop a more comfortable flame-resistant shirt fabric. The new fabric has a more open, thicker weave. Weight and fire resistancy remain the same. Forest Service field evaluators said the new shirts are cooler on hot days and warmer on cool nights. The openness of the weave improves evaporative cooling while its thickness traps air next to the skin to keep the wearer warmer at night.

The fabric feels softer, too, evaluators said. The softer fabric should reduce chafing problems some people experienced with the previous Nomex® shirts.

To insure a better fit for more people, the shirts are being made in a new extra-small size.

Key features of the earlier design have been retained. Sleeves are cut full for ventilation plus free movement of the arms. This reduces fabric stress at the elbows and improves durability of the shirt. For added protection against radiant heat and falling embers, the collar can be turned up. Sleeves can be drawn snugly around the wrists with quick-fastening Velcro® closures. Buttons are oversized for easy fastening. Two large pockets with flaps hold maps, note pads, and similar items. The shirt can be worn inside the trousers, or outside of the jacket. Wearing the shirt inside offers the most thermal protection.

Flame-Resistant Jeans

The firefighters pants were re-designed into a basic jean cut. For greater comfort, they have a little fuller cut in the crotch, upper leg, and seat. The new jean design features western scoop front pockets and a return to hook and pile tabs on the back pockets. These pockets remain large for carrying extra personal items and to increase thermal protection with a double layer of fabric.

The zipper fly was retained, but the waistband is now closed with a traditional metal jean rivet button. The button is embossed with the letters FSS for Federal Supply System.

These jeans also come in two new waist sizes: 26 inch and 40 inch. And there is a choice of two inseam sizes, 30 and 34 inches. For those who need 31- or 32-inch inseams, it is easier to let out the 30-inch inseam than to cut and re-hem the 34 inch. The 34-inch inseam can be let out to inseams of 35 to 36 inches.

What To Wear with Nomex®

The other clothes worn with Nomex® shirts and jeans affect their protective qualities. Underwear of a polyester cotton blend is acceptable, but we recommend T-shirts and undershorts of 100 percent cotton. All-synthetic underwear should never be worn. Two layers of clothing, that is Nomex® plus underwear, provide better thermal protection. *But don't wear other work clothing under or over your Nomex® garments.* Doing so increases body heat and puts an added load on the heart.

For colder weather and nights, jackets should be all wool, all cotton, or wool blends of at least 85 percent wool.

Coveralls or Jumpsuits

Firefighters in some agencies wear Nomex® or FRT cotton coveralls or jumpsuits, and we are often asked why the Forest Service doesn't use them.

We favor shirts and pants and discourage coveralls and jumpsuits for these reasons: (1) Coveralls are usually worn over other garments. This restricts body cooling, which results in higher heart rates and increased heat stress. (2) Coveralls are made from a single-weight fabric, but ideally different weight fabrics are needed for the upper and lower parts of the body; for example, a heavier, more durable fabric to protect legs from brush and general abrasion, and a lighter-weight fabric with a more open weave to help dissipate heat from arms, chest, and back. One-piece garments of a heavy trouser-weight fabric, like work coveralls, restrict cooling. They also chafe parts of the upper body if worn only over T-shirts. Jumpsuits are made from shirt-weight fabric and do not provide

adequate leg protection. (3) Fire-fighter's clothing is produced in a limited number of sizes to keep costs down. With such a limited size distribution, one-piece garments seldom fit many people properly because the distance between crotch and shoulders varies so much. In a work situation this causes chafing and discomfort. (4) One-piece garments made from flame-resistant fabrics are expensive. Unlike shirts and jeans, if part of the garment becomes unserviceable, the entire garment must be replaced.

Flame-Resistant Gloves

Specially designed gloves are essential in protecting the fire-fighter's hands against blisters, scratches, small cuts, and minor burns during routine firefighting. But they also play a major fire protection role in event of an aircraft accident or fireline entrapment.

Reviews of past fire entrapments show that those trapped burned while attempting to flee entrapment sometimes lost fingers if they were not wearing gloves or if their conventional oil-tanned work gloves burned or shrunk from intense heat. Additionally, reports from people entrapped in shelters emphasize the importance of gloves in holding down hot shelter material without getting burned.

After numerous material and design changes, MEDC's latest model forest workers' gloves appear to be meeting firefighting and general

forestry requirements very well.

The new gloves are full-grain, chrome-tanned leather; previous models were split-grain leather. Full-grain leather is stronger, so the new gloves wear better and last longer. Full-grain leather requires narrower seam margins to hold stitches, which reduces bulk. Compared with oil tanning, chrome tanning provides excellent protection against heat and shrinkage. These gloves also resist stretching and retain their shape better wet or dry because the leather is water and oil resistant.

A drawstring wrist closure keeps embers and debris from getting into the gloves.

Leather Boots and Wool Socks

Past fire entrapment investigations found that good quality leather boots traditionally worn for wildland fire-fighting provide adequate foot protection. All-wool or mostly wool socks offer added thermal protection. Wool wicks moisture from the skin. This helps keep feet cooler and dryer, reducing the chance of blisters, a common firefighting injury.

The Forest Service requires the firefighter to wear a lace-type leather boot with at least an 8-inch top. Skid-resistant soles are required, with a lug-type sole preferred. Slips and falls account for many fire-fighting injuries. One study over a 10-year period indicates that 17 percent of injuries result from slips and falls. So the importance of good skid-resistant soles cannot be over-

emphasized.

Chain Saw Chaps

One last piece of PPE that we'd like to review is chain saw chaps. Since not all firefighters wear them, we don't include chaps as a component of the basic PPE system. However, due to the extensive use of chain saws in firefighting, we feel a brief review of this item is appropriate.

Chain saw chaps were redesigned in 1982. The redesign focused on increasing sawyer protection and comfort while minimizing costs.

MEDC tested many combinations of materials to find the best protection with the least weight. The new outer shell is 11-ounce Cordura® nylon, replacing the bulky 15-ounce cotton canvas. Cordura® cleans easily, resists tears and abrasions, and keeps the protective pad free of oil better than cotton canvas. The protective pads combine two layers of woven Kevlar® with two layers of Kevlar® felt. Kevlar® is an aramid fiber like Nomex®, but with more flame resistance. Moreover, because of its cut resistance, it can slow and quickly jam the chain before cutters penetrate the leg. At 2 pounds, the new chaps weigh 40 percent less than the old style and offer 50 percent more protection.

Quick-release buckles make the chaps easy to put on and take off. This is a nice feature for firefighting because the chaps can be easily removed to reduce heat stress when

sawing is completed. Leg straps have been relocated to improve fit and minimize snagging, and a tool pouch was added to hold a round file, file guide, flat file, spark plug wrench, and screwdriver. A pamphlet titled "Inspecting and Repairing Your Chain Saw Chaps" is available from the MEDC.

Respiratory Protection

Even though the personal protective system doesn't include any kind of breathing device, we want to discuss briefly respiratory protection.

As we pointed out above, the fire shelter protects the firefighter's airways and lungs during fire entrapment. But what about protecting the working firefighter's respiratory system from smoke, dust, and hot gases?

Periodically, MEDC has been funded to search for effective, practical respiratory protection that does this. Self-contained breathing apparatus used by municipal and industrial firefighters are effective but impractical for wildland firefighting. The Center has tested various types of respirators, and all restrict breathing and don't filter gases well, exposing the wearer to high concentrations of poisonous carbon monoxide and other toxic gases. For this reason, we haven't been able to recommend respirators.

For limited smoke and dust protection, firefighters have worn bandannas for years and are beginning to use disposable dust filters. Bandannas or dust filters should be kept dry. In intense heat, as when working against a hot flame front, there is a possibility that breathing hot, moist air through a wet dust filter or bandanna can damage the respiratory system.

Furthermore, firefighters should be cautioned against covering too much of the face. Cheeks and ears are excellent heat sensors. Covering them can lead a person to work too long in a hot situation. The result can be dehydration, heat stress, and prolonged elevated heart rate leading to premature fatigue, or worse.

Conclusion

Improvement of personal protective equipment is a dynamic process. Materials and production technology change constantly. And new knowledge, particularly in the arena of human physiology, is expanding rapidly. The staff at the Missoula Equipment Development Center keeps up with these changes so as to continue to improve personal protective equipment for the wildland firefighter. We always welcome comments on product improvements. ∎

Using Interactive Videodisc Technology in Wildland Fire Behavior Training

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In recent years, fire research has developed a large body of complex information. Proper wildland fire management and use requires a thorough understanding of combustion, fire behavior, fire ecology and history, fire economics, fire effects, and prescribed fire practices. Large areas of valuable resources and human lives are often at stake during prescribed fire and fire suppression activities, making thorough, up-to-date professional training essential. Because safety is such an overriding concern, adequate training is mandatory to reduce risk.

Most fire management organizations require approximately 40 hours of formal training as a basic prerequisite to any entry level suppression position. The curriculum includes fundamentals of fire behavior, fire suppression, fire organization, tool and equipment use, and safety. Fire behavior is central to this curriculum, and a subject taught by all fire management agencies. A complete, multilevel instructional package developed by the National Wildfire Coordinating Group (NWCG) is the training standard in fire behavior for all NWCG agencies.

Our project involves using existing fire behavior curricula in an interactive videodisc/computer training system. This disc will supplement existing training courses in wildland fire behavior and will include materials produced by NWCG on introductory, intermediate, and advanced fire behavior. In addition, elements from existing courses on fuels inventories, debris prediction, and prescribed fire will be included on the program (9).

The objective of this project is to demonstrate the application of interactive videodisc instruction to wildland fire management by producing a program on wildland fire behavior. This training package will not replace existing instructional materials, but will act as a supplement to current training materials. The project is funded by NWCG and is being administered by Bureau of Land Management, Division of Training, Boise Interagency Fire Center.

Interactive Training and Instruction

Basic principles of interactive design must be clearly understood in order to realize the benefits which can occur through the use of an interactive training medium. In order to provide useful interaction between the learner and the instructional program, intellectual options should be provided that allow users to actively make decisions and be subjected to their consequences (1). For example, an incorrect calculation of a fire's rate of spread in a given simulation may result in inappropriate tactical response to the incident. Learners make choices, and the system responds, sometimes in surprising ways. An interactive videodisc lesson should allow learners to "create" their own training experience, to interview and make frequent decisions about the content of the lesson and the way it is delivered.

The instructional system responds instantly to learner input by providing relevant, previously designed instructional cues, reinforcement, and feedback segments composed of computer text and graphics, still and motion video, with or without audio. The scope, sequence, rate, style, duration, level, and medium of instruction is, to a large degree, determined by a dialog between the learner and the system.

The linear, presequenced format of most traditional instructional materials such as texts, workbooks, films, or slide/tape presentations treats all learners alike and does not allow the learner to actively take part in the choice of sequence or content of a lesson (5).

Interactive video is a powerful medium, bringing together the emotional impact of video and film and the interactive capabilities of the computer. Development of interactive videodisc instruction has, to a large degree, mirrored computer-assisted instruction (CAI). Like CAI, interactive videodisc instruction can be used as a tutorial, for drill and practice and in simulations, as well as for information storage.

Designing Interactive Videodisc Instruction

The process of designing, writing, directing, and producing an interactive videodisc/computer lesson in wildland fire behavior is very similar to the basic design and production of an instructional film. However, the major challenge is the integration of various media, designing the dynamic relationship between user and the system, and working with a modular, rather than a linear medium (4).

Instructional Matrix. A content matrix for the instructional package in wildland fire behavior was initially developed from a careful analysis of program goals and objectives, existing course materials, learner characteristics, and the various forms of media used within the disc to be selected. This matrix lists the appropriate instructional segments classified by topic and intended learner group in a matrix structure. The matrix thus acts as a "map" to guide the designer in creating the dynamic flowchart that represents the interactive branching training program.

Interactive instruction is designed to be modular and nonlinear, with hundreds of preplanned options available to learners based on prior knowledge of their unique interests, abilities, feedback preferences, primary language ability, and learning styles (fig. 1).
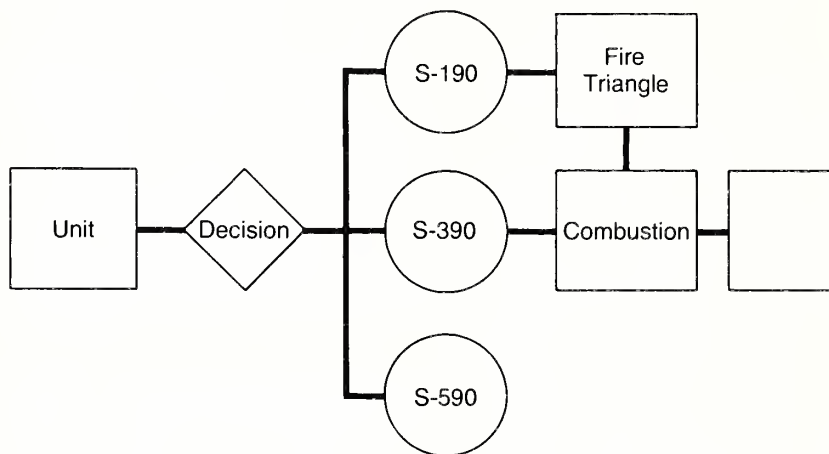
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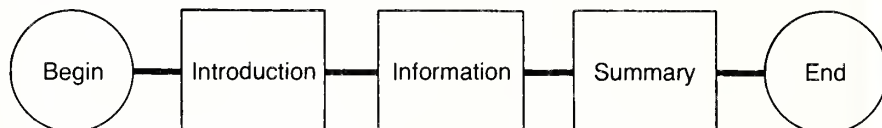
Figure 1—*Linear versus interactive instruction. A linear program has a predetermined format, whereas an interactive program allows the learner to make choices.*

is made possible through a process called branching. A branching program has alternate tracks for the rapid and slow learner, can follow up certain responses in detail, allow learners to see only the materials they need or want to see, test learners on the comprehension of the materials, allow learners to repeat material or to have remedial work when needed, and effectively pose a question without demanding one unique, correct answer. Although branching has been extensively used in computer-assisted instruction,

there have been disruptive weaknesses in the quality of video imagery and search time for sequences. The introduction of videodisc technology has been an obvious and practical solution to these problems.

Flowcharting. The branching system developed for the instruction must be graphically represented as a flowchart. The flowchart depicts all instructional events that will be included in the wildland fire behavior training program for the various specified audiences. The flowchart shows each instructional

frame, both still frames and motion sequences, all branching options, menu driven and under program control, all "help" routines, all test items, and dedicated jump forward and review options.

The procedures used in flowcharting interactive instruction are similar to those used in any flowcharting operation. Symbols are very nearly the same, with a few variations to allow for easy identification of the nature of the instructional frame, whether it is a still of freeze frame, or motion sequence. A sample flowchart is shown in figure 2 to demonstrate the complexity involved in the development of an interactive lesson in wildland fire behavior.

Script, Narrative Writing, and Graphics. After the major elements of flowchart construction are completed, scripts and narratives must be written, including all text, computer and quiz screens, and test items. Special terms are used to help integrate the various media, and keep track of hundreds of instructional segments that will be used to individualize instruction for a variety of learners. Scripts and storyboards are then drafted and reviewed for content, style, and feasibility; graphics, animation, and special effects are also planned at this time. Formative evaluation and revision are also appropriate at this stage of design.

Preproduction. The preproduction phase of an interactive videodisc

is very similar to that of a film or videotape. However, there are some steps unique to the videodisc medium, including the mapping of the "geographical" layout of the disc, writing of the accompanying computer program, and locating the simple time code numbers for the video frames from the master tape. These steps must be completed before the final production and the mastering of the videodisc (4, 11).

Production details will not be discussed, as basic production for a videodisc is almost identical to that of other media such as videotape or film. Once a master videotape of the training materials is edited and contains all instructional sequences, the tape is sent to one of five mastering houses, where the visual images and audio are transferred onto a videodisc.

Hardware and Software Considerations

Intaractive videodisc training is orientad toward the development of learning stations for individual and small group learning. Interactive instruction can take place in any location where an individual or small group can have access to a computer that controls several peripherals, including a videodisc player and monitor (fig. 3 and 4). Input to the computer can be through a touch screen, light pen, or keyboard. The video output from

the computer, as well as video/audio from the disc, appears on a single screen or two separate screens. The delivery system chosen for this project uses one screen, allowing both video from the videodisc, and text over the video, which is generated by the computer. "Windows" of video can be opened to illustrate a point described by computer text, or lettering can be written over a video image.

The hardware configuration selected for this project includes an IBM PC computer, Pioneer LD V-1000 videodisc player, and Zenith color monitor. Programming is being done using an authoring system called "Quest."

Expected Benefits

Interactive videodisc technology has proven to be a powerful educational tool, using computer-based learning systems that can display high-quality video imagery, provide rapid access to images, and utilize quality audio. The individualized, self-paced format represented by videodisc instruction focuses on learner needs, rather than a predetermined pace and sequence. A learner is able to choose among a variety of instructional options, and learning is directed according to performance and measurements of understanding. Interactive videodisc allows learners to have remedial
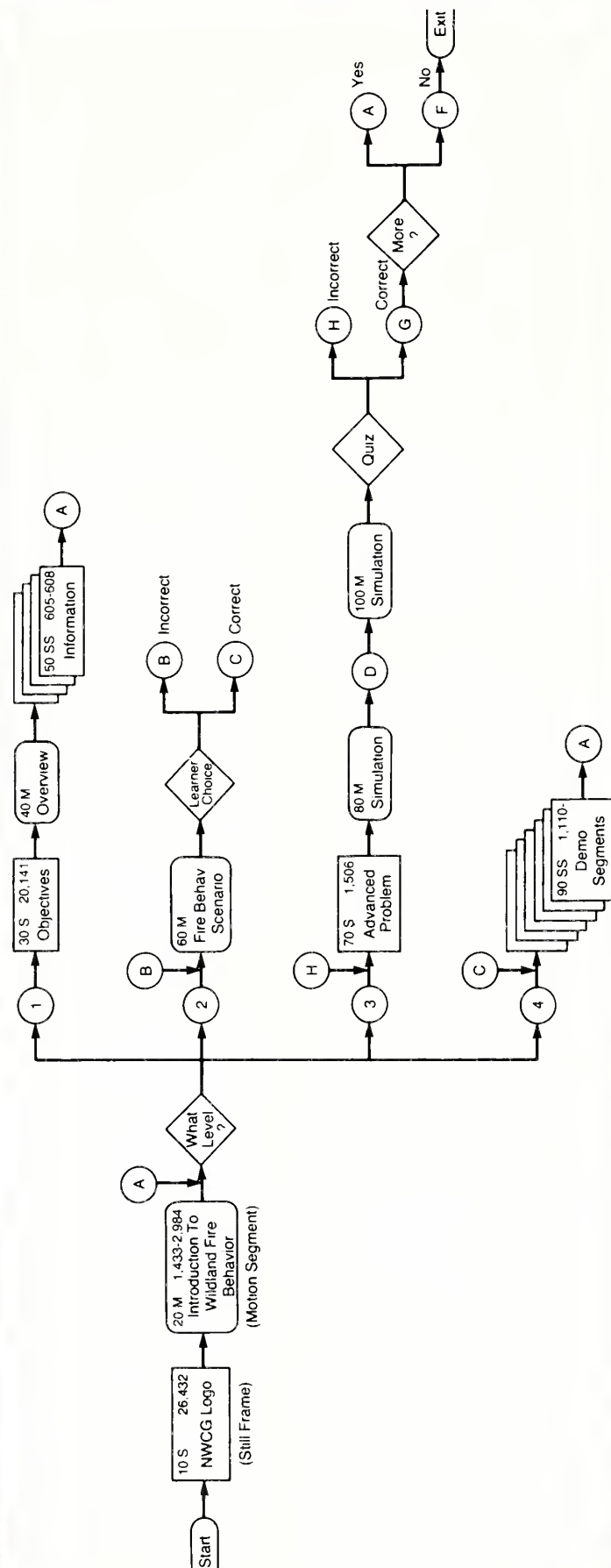
Figure 2—*A sample flowchart showing the complexity of the development of an interactive lesson.*
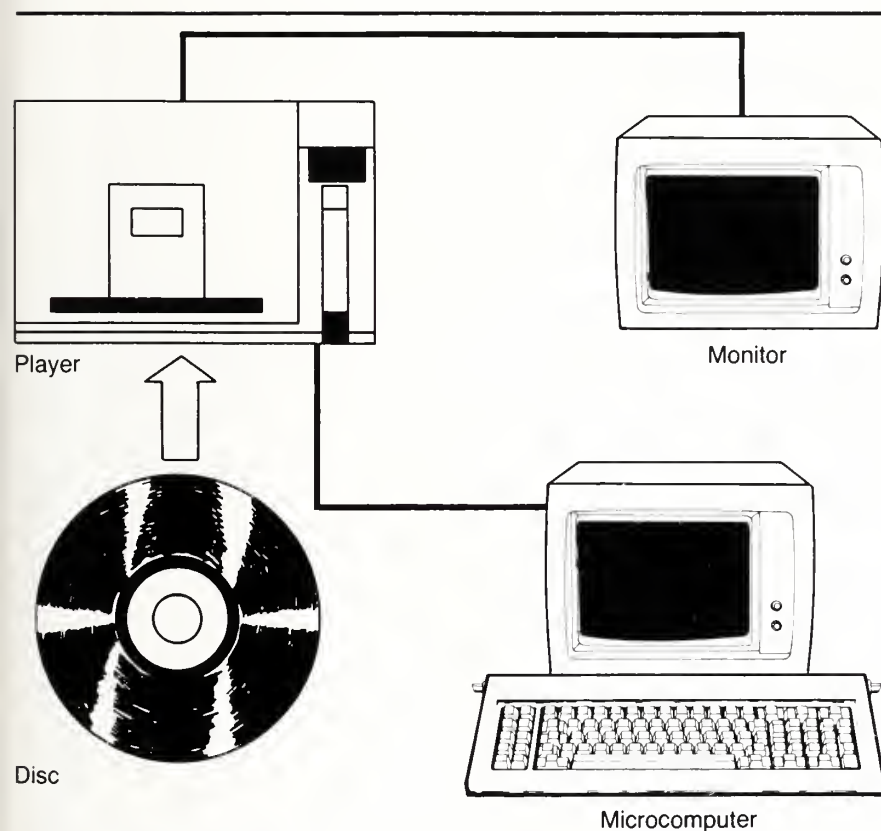
Figure 3—*Hardware components of an interactive videodisc/microcomputer system.*

Because of the huge storage capacity of a videodisc, beginning, intermediate, and advanced fire behavior training courses can be placed on one disc, allowing the learner to seek remedial help when necessary or go on to advance material when desired. Fire behavior simulation exercises can also be included, allowing learners to apply their knowledge of fire behavior in lifelike scenarios requiring management decisions. Such simulations are more versatile and ''transportable'' than previously developed fire simulators, and can be used in small or remote centers or for individual use for review or training. The incorporation of tutorial lessons, as well as drill and practice, test items, and information storage make interactive videodisc an efficient, space-saving medium for instruction and a potentially powerful training tool for fire managers and personnel.

work if needed or skip ahead if prior mastery is demonstrated.

Other benefits of using interactive systems include: the use of programs by either individuals or small groups, flexible scheduling of training, ease of transport of instruction to remote training sites, and training costs much lower than for traditional training methods.

Recent studies in the comparison of videodisc instruction to traditional methods of instruction have shown numerous advantages from the use of interactive videodisc. Such factors include: savings in actual learning time, higher mastery rate, and favorable response to the medium. Other cost-related benefits are less time spent away from the job, reduced travel/living expenses for training, reduced need for classroom instructors, and use in remote training stations (6, 7).

Fire behavior training naturally lends itself to the videodisc medium.

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Figure 4—*Videodisc training systems can be used either by individuals or small groups working together.*

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Florida State Forester John Bethea accepts the Golden Smokey Award from Regional Forester Jack Alcock. Mr. Bethea received this award in recognition of his total commitment to protecting America's forests from wildfire.

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